Chapter 4

CAT175, NY

Ozone Concentrations

CASTNet is considered the principal source of information on rural O_3 concentrations in the United States. CASTNet O_3 data provide information on geographic patterns in regional O_3 and on the extent to which rural areas potentially exceed the concentration levels mandated by the NAAQS. Three to five sites typically experienced 1-hour concentrations above 125 ppb each year over the period 1990 through 2002. During the same period approximately 30 to 50 percent of CASTNet sites measured fourth highest daily maximum 8-hour O_3 levels above 85 ppb. Measurements of 1-hour and 8-hour concentrations and SUM06 levels during 2002 were considerably higher than in 2001 and 2000.

Ozone in the Atmosphere

Ozone is an important gas that occurs naturally in the atmosphere in trace amounts. Most atmospheric ozone (about 90 percent) occurs in the stratosphere, a region 20 to 30 km above sea level, where it peaks at about 100 parts per million (ppm). This region is called the ozone layer. Ozone concentrations also occur in the troposphere, near ground-level, and are about 10 ppb (0.1 ppm) in pristine regions of the earth. Certain types of anthropogenic emissions deplete O_3 in the stratosphere while other emissions increase tropospheric ozone. Stratospheric O_3 plays a critical role in absorbing the sun's ultraviolet radiation, which can harm surface cells of plants and animals and cause increased skin cancer in susceptible individuals. On the other hand, elevated O_3 concentrations near ground level can lead to adverse respiratory effects in humans and reduced plant vitality. This ozone paradox has been described extensively in literature. The EPA ozone web site (www.epa.gov/ozone/science/) provides information about atmospheric ozone.

Stratospheric ozone concentrations have decreased from levels measured around 1970 and are not expected to recover to 1980 levels until the middle of the century. During this same period, tropospheric O_3 concentrations have increased. For example, measurements taken in EPA Region 4 (southeastern United States) show an increase in fourth highest daily maximum O_3 concentrations from an average of 78 to 91 ppb over the period from 1989 through 1998. CASTNet O_3 data show persistent high concentrations at rural sites.

Tropospheric ozone levels vary by region and are influenced by emission sources, terrain, temperature, sunlight, air stagnation periods, and other factors. CASTNet data show significant variability. For example, CASTNet stations measured annual mean concentrations of 26.7 ppb, 43.6 ppb, 24.7 ppb, and 32.6 ppb during 2002 at BEL116, MD (suburban), PNF126, NC (mountainous), VII423, VI (tropical), and DEN417, AK (northern-most), respectively (Figure 4-1). These sites exemplify different land use and terrain settings. The highest mean O_3 concentration of 53.5 ppb was measured at JOT403, CA, a high elevation site downwind of Los Angeles. The lowest mean concentration of 13.6 ppb was measured at OLY421, WA, a cloudy, wet location.

CASTNet and other databases provide an extensive record of O_3 observations. Most sites, especially urban sites, show a distinct diurnal cycle of ozone concentrations with a minimum in the early morning around dawn and a peak in the late afternoon. Figure 4-2 shows the average diurnal cycles for BEL116, MD, PAR107, WV, and PNF126, NC during 2002. The differences in the three diurnal curves can be explained by several factors: the proximity of the monitors to source regions; day-night differences in photochemistry, scavenging, and dry deposition; and terrain and atmospheric boundary layer effects. The suburban site (BEL116) shows significant variability with the lowest values in the morning near sunrise and an afternoon daily peak that is three to four times early morning levels. Mean hourly values from PAR107, a complex terrain site, also indicate significant day/night variability. Daytime values are about twice nighttime values. The mountaintop site (PNF126) shows a flat diurnal pattern with little variability from hour to hour.

Suburban O_3 concentrations are influenced typically by nearby sources and nighttime depletion mechanisms. Ozone depletion mechanisms include dry deposition and reaction with nitric oxide (NO) at night, when photochemical production ceases and vertical transport of ozone-rich air from above is inhibited by a ground-based inversion layer. In many suburban areas, NO levels are high enough at night to eliminate O_3 altogether. In short, suburban sites show more day/night change, have low early morning concentrations, and have relatively lower annual mean O_3 concentrations because of nighttime depletion.

Complex terrain sites are subject to the effect of nighttime inversions and dry deposition losses, but most likely not by locally produced, fresh NO emissions, which would scavenge O_3. Hence, nighttime and early morning O_3 levels are low, but day/night changes are less pronounced than at suburban sites. Annual mean concentrations generally fall between those measured at mountaintop and suburban sites.

Sites near mountaintops are situated typically at elevations above the tops of nocturnal boundary layers. These sites are generally exposed to the ozone that exists in the planetary boundary layer at night above ground-based inversions. O_3 at these elevations is not depleted by dry deposition or by scavenging by low-elevation NO emissions. Concentrations are relatively constant throughout 24 hours and are relatively high on an annual basis.

Ozone concentrations vary significantly from day-to-day, as local and regional meteorological conditions and emissions change. Figure 4-3 provides time series of highest daily maximum 1-hour O_3 concentrations at the same three sites (BEL116, PAR107, and PNF126) for 2002. BEL116 measured the highest hourly concentrations and observed the largest daily variability. The mountaintop site at PNF126 showed the lowest daily variability and recorded the highest concentrations during the winter months.

NO_x species are important in the chemistry of the troposphere. Gas-phase chemistry involves the oxidation of organic molecules in the presence of NO_x under the action of sunlight. O_3 can be considered the principal product of tropospheric chemistry. When NO and NO_2 are present in sunlight, O_3 is formed as a result of the photolysis of NO_2:

$$NO_2 + hv \rightarrow NO + O \quad (4.1)$$

$$O + O_2 + M \rightarrow O_3 + M \quad (4.2)$$

where hv represents incoming solar radiation and M represents another third molecule. Reaction 4.2 is the only significant source of ozone in the atmosphere. Once formed, O_3 reacts with NO to regenerate NO_2:

$$O + NO \rightarrow NO_2 + O_2 \quad (4.3)$$

Measured O_3 concentrations frequently exceed those predicted by Reactions 4.1 through 4.3. Other reactions involving carbon-containing species enhance the production of O_3 by producing free radicals that oxidize NO to NO_2 and subsequently to O_3 via Reaction 4.2. In the "background" troposphere, the oxidation of methane and carbon monoxide (CO) contribute to O_3 formation. Background O_3 concentrations are produced by methane and CO oxidation, transport from the stratosphere, and very long-range transport. In more polluted locations, the chemical reactions of volatile organic carbons (VOC) such as alkanes, alkenes, and aromatic hydrocarbons and NO_x dominate over methane and CO chemistry. Biogenic VOC contributes to O_3 formation in rural areas. VOC emission reduction strategies have been successful in reducing the higher short-term O_3 concentrations in and downwind of urban areas. However, ultimately, NO_x emission reductions will be required to reduce O_3 concentrations, especially elevated 8-hour levels in rural areas.

National Ambient Air Quality Standards for O_3

The Clean Air Act requires EPA to set NAAQS for pollutants considered harmful to public health and the environment. EPA promulgated two types of national standards: primary standards to protect public health and secondary standards to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings. EPA has recently promulgated a new 8-hour primary NAAQS (EPA, 1997). This standard is achieved when the 3-year average of the fourth highest daily maximum 8-hour concentration does not exceed 0.08 ppm (85 ppb in practice). A second primary standard for 1-hour O_3 concentrations is gradually being replaced by the new 8-hour primary NAAQS. The NAAQS for 1-hour O_3 concentrations is achieved when the daily maximum 1-hour concentration does not exceed 0.12 ppm (125 ppb in practice) more than once per year, averaged over three consecutive years. The achievement of these standards is gauged though continuous ambient air monitoring data. EPA will continue to apply the 1-hour NAAQS to areas that have been determined to be nonattainment areas for this standard until the area has attained the standard as indicated by three consecutive years of compliant air quality data. EPA decided to retain the 1-hour standard to ensure a smooth, legal, and practical transition to the 8-hour NAAQS.

One-Hour Concentrations

Figure 4-4 presents the second highest daily maximum 1-hour O_3 values for 2002. Many CASTNet stations measured 1-hour concentrations greater than 100 ppb. The two regions measuring the highest concentrations included sites with concentrations in excess of 125 ppb. One region is located on the East Coast and extends from Maryland to southern New England. The second region is located in southern California. BEL116, MD, WSP144, NJ, ABT147, CT, and JOT403, CA measured second highest daily maximum 1-hour concentrations above 125 ppb during 2002.

Eight-Hour Concentrations

EPA is currently determining attainment and non-attainment areas for the 8-hour primary NAAQS, which was promulgated to protect human health and welfare (e.g., vegetation). Figure 4-5 presents a map of the fourth highest daily maximum 8-hour O_3 concentrations measured during 2002. Twenty-nine eastern and five western sites, four of which are in California, measured values above 85 ppb. The highest concentration (109 ppb) was observed at SEK402, CA. Six other sites measured concentrations greater than 100 ppb. The geographic extent of the high 8-hour concentrations was considerably larger during 2002 than 2001. A majority of eastern sites measured 8-hour concentrations above 85 ppb. An 8-hour concentration of 87 ppb was measured at ROM406, CO. The lowest daily maximum 8-hour concentration in the continental United States was measured at OLY421, WA with a value of 27 ppb.

SUM06

SUM06 is a measure of vegetation and crop exposure to ozone during the growing season. SUM06 is calculated as the sum of hourly O_3 concentrations greater than 0.06 ppm summed over 12 hours (0800 to 2000) during a 3-month period. SUM06 is measured in units of parts per million-hours (ppm-hrs). EPA had considered SUM06 as a potential secondary NAAQS for O_3. However, EPA selected the 8-hour NAAQS as both a primary and secondary standard instead.

Figure 4-6 presents a map of peak SUM06 values for 2002. The peak values were taken as the maximum rolling 3-month SUM06 at each CASTNet site. The map shows that a majority of CASTNet sites measured SUM06 values greater than 25 ppm-hr. A band of elevated SUM06 levels was observed from southern California to the East Coast. The highest SUM06 value of 91.1 ppm-hr was measured at SEK402, CA. The lowest values were observed in the Northwest and along the northern tier of the United States. Similarly, low SUM06 values were measured from eastern Arizona to Florida.

Ozone Flux

Figure 4-7 presents a map of modeled 2002 ozone fluxes. These estimates represent the dry deposition of O_3 to the environment. Ozone dry deposition fluxes greater than 50 kg/ha/yr were simulated for several CASTNet sites in several states, including New York, New Jersey, Pennsylvania, West Virginia, Virginia, North Carolina, Tennessee, Kansas, and Wyoming. These high fluxes reflect the high O_3 concentrations measured during 2002. The two highest fluxes were modeled for KNZ184, KS (71.0) and GRS420, TN (68.6). The MLM modeled V_d for KNZ184, KS (0.27 cm/sec) and GRS420, TN (0.26 cm/sec) were the highest in the network. The lowest flux for CASTNet sites in the continental United States (20.3) was simulated for NCS415, WA.

Thirteen-Year Trends

The 13-year trend in the second highest daily maximum 1-hour O_3 concentrations is given in Figure 4-8. The box plot was prepared using the same 34-station subset of data used in all the trend analyses. The figure shows that 2002 aggregated concentrations were significantly higher than those measured in 2001. The 2002 median value was approximately 25 percent higher than the median for 2001. The box plot suggests no trend in the aggregated measurements. No formal statistical analyses were performed and trends were not analyzed for individual monitoring sites.

Figure 4-9 presents a box plot of fourth highest daily maximum 8-hour average O_3 concentrations. The figure shows that relatively high 8-hour O_3 concentrations were measured during 2002. The box plot shows that 2002 values were almost as high as those measured during 1999. The median value for 2002 is the third highest over the 13-year period. No overall trend is evident in the aggregated data.

The trend in SUM06 is illustrated in Figure 4-10. The box plot shows that relatively high ozone exposure, as measured by SUM06, was experienced in 2002. In short, 2002 was a high ozone year after two low years. No trend is evident in the SUM06 data.

Thirteen-year trends in temperature, solar radiation, and precipitation from the 34 eastern reference sites were analyzed for the period May through September, the nominal ozone season, for most of the 34 sites. All hourly temperature and solar radiation values were averaged by site and all precipitation amounts were summed. Box plots (Figures 4-11 through 4-13) of temperature, solar radiation, and precipitation were prepared for the 13-year period to provide perspective to the box plots of the three sets of O_3 parameters (Figures 4-8 through 4-10). The qualitative relationship between O_3 concentrations and the three meteorological parameters is evident from the six box plots. The year 2002 had relatively high temperatures and sunny skies with average precipitation. The median temperature and solar radiation values were the second highest over the 13-year period. Consequently, the year 2002 experienced high O_3 concentrations. In general, relatively high concentrations were measured during warm, sunny years (e.g., 1991 and 1999); and relatively low concentrations were observed during cool, cloudy years (e.g., 1992 and 2000).

Evaluation of One-Hour and Eight-Hour Concentrations

Although CASTNet was designed to measure rural regional air quality, several monitoring stations measured hourly O_3 concentrations above 125 ppb, which are more typically expected to be measured in urban areas. Table 4-1 shows the CASTNet sites that observed O_3 levels above 125 ppb during at least three of the six 3-year periods between 1995 and 2002. Other sites in the network observed concentrations greater than 125 ppb, but not for a minimum of three 3-year periods.

The BEL116, MD site consistently measured 1-hour O_3 concentrations above 125 ppb during four or more days in each 3-year period. The monitoring stations at ABT147, CT and WSP144, NJ have also measured frequent, consistently high O_3 concentrations since 1997. The site at JOT403, CA, which is downwind of Los Angeles, observed some of the highest hourly O_3 concentrations in the network. The site at GAS153, GA, which is southwest of Atlanta, measured no concentrations above 125 ppb over the last two 3-year periods, even though during previous three 3-year periods it measured elevated levels. Although other CASTNet sites measured an occasional 1-hour concentration greater than 125 ppb, the five sites in Table 4-1 are the only sites in the network that measured hourly O_3 levels greater than 125 ppb for more than three days in a 3-year period. The five sites represent about 5 percent of the approximately 100 different monitoring sites that have been operated during the period from 1990 through 2002.

Table 4-2 presents 3-year averages of the fourth highest daily 8-hour O_3 concentrations over the period 1995 through 2002. Sixty-nine sites were identified with valid 3-year averages for every 3-year period since 1995. Grid cells that are shaded indicate those sites that observed O_3 levels at or above 85 ppb for that period. Twenty sites recorded values at or above 85 ppb. Recall that 2000 and 2001 were relatively low O_3 years. About half the sites recorded exceedances during the two 3-year periods, 1997-1999 and 1998-2000. SEK402, CA recorded an 8-year average of the fourth highest daily maximum O_3 concentration in excess of 100 ppb.

Table 4-3 shows the number of days per year for each site that the 8-hour O_3 concentration equaled or exceeded 85 ppb. Several sites experienced elevated 8-hour concentrations more than 20 days per year. SEK402, CA averaged more than 30 days per year with a peak of 81 days in 2002. Other sites that experienced frequent 8-hour O_3 concentrations include JOT403, CA, GRS420, TN, and the two Maryland sites. Most sites experienced at least one year with ten or more occurrences of elevated O_3 levels. The frequency of high (≥ 85 ppb) is related qualitatively to the pattern of meteorological events illustrated in Figures 4-11 through 4-13.

Table 4-1. Number of Days at CASTNet Sites with Hourly O_3 Concentrations Greater Than or Equal to 125 ppb over 3-Year Periods

Site ID and Location		1995-1997	1996-1998	1997-1999	1998-2000	1999-2001	2000-2002
ABT147	Abington, CT	4	-	4	4	6	7
BEL116	Beltsville, MD	4	7	11	11	7	8
GAS153	Georgia Station, GA	4	5	-	5	-	-
JOT403	Joshua Tree NM, CA	18	23	20	12	-	4
WSP144	Washington's Crossing, NJ	-	-	9	9	11	7

Table 4-2. Three-Year Averages of Fourth Highest Daily Maximum 8-Hour Average O_3 Concentrations for CASTNet Sites* (Page 1 of 2)

Site ID	1995-1997	1996-1998	1997-1999	1998-2000	1999-2001	2000-2002
ABT147, CT	91	90	94	90	95	98
ALH157, IL	92	91	92	89	86	86
ANA115, MI	81	82	86	86	87	86
ARE128, PA	87	90	91	90	88	94
ASH135, ME	64	62	65	62	64	65
BBE401, TX	67	68	65	66	63	62
BEL116, MD	97	97	102	100	98	98
BFT142, NC	74	80	83	81	76	74
BVL130, IL	89	89	90	91	85	83
BWR139, MD	96	97	101	100	98	96
CAD150, AR	77	79	84	85	81	78
CAN407, UT	68	70	70	73	71	71
CAT175, NY	75	71	79	77	0	60
CDR119, WV	76	81	84	84	79	75
CDZ171, KY	82	83	89	89	85	83
CHA467, AZ	68	68	68	70	70	69
CKT136, KY	87	88	87	88	83	83
CND125, NC	85	92	94	93	86	84
CNT169, WY	69	71	72	74	75	75
COW137, NC	70	72	75	79	77	75
CTH110, NY	82	84	84	82	80	83
CVL151, MS	76	78	82	85	82	77
DCP114, OH	87	92	95	96	88	85
DEV412, CA	74	79	79	80	79	81
ESP127, TN	78	80	83	82	79	75
GAS153, GA	93	96	96	99	91	89
GLR468, MT	47	50	47	51	48	49
GRB411, NV	71	72	72	73	72	72
GRC474, AZ	71	72	73	73	72	73
GTH161, CO	71	72	73	73	73	71
HOW132, ME	63	63	71	68	69	68
HOX148, MI**	—	—	—	—	—	81
JOT403, CA	109	112	109	102	92	94
KEF112, PA	79	81	82	84	83	84
LAV410, CA	71	72	76	78	77	74
LRL117, PA	89	87	86	76	72	73
LYE145, VT	82	83	83	84	41	67
LYK123, OH	76	78	89	87	85	88
MCK131, KY	86	89	91	91	84	84
MCK231, KY	85	88	91	91	84	85
MEV405, CO	65	67	66	70	69	69

Table 4-2. Three-Year Averages of Fourth Highest Daily Maximum 8-Hour Average O_3 Concentrations for CASTNet Sites* (Page 2 of 2)

Site ID	1995-1997	1996-1998	1997-1999	1998-2000	1999-2001	2000-2002
MKG113, PA	86	87	87	87	85	87
MOR409, WA	52	52	51	57	60	56
NCS415, WA	44	43	43	46	48	46
OXF122, OH	86	89	91	91	85	86
PAR107, WV	77	79	82	83	80	79
PED108, VA	78	81	86	85	83	82
PIN414, CA	84	86	82	82	79	81
PND165, WY	66	69	70	71	71	71
PNF126, NC	77	81	84	86	83	82
PRK134, WI	68	67	74	75	77	72
PSU106, PA	92	89	92	86	87	87
QAK172, OH	85	85	93	91	88	86
ROM406, CO	72	74	74	77	74	78
SAL133, IN	89	86	86	85	84	84
SEK402, CA	101	100	102	102	103	103
SHN418, VA	85	92	96	93	87	85
SND152, AL	88	89	91	93	89	84
SPD111, TN	77	80	86	89	84	87
STK138, IL	81	80	79	80	81	79
SUM156, FL	71	76	78	79	74	70
UVL124, MI	85	84	88	83	84	80
VIN140, IN	84	86	87	86	82	83
VOY413, MN	66	66	70	68	67	64
VPI120, VA	79	84	89	89	84	83
WEL149, MI**	83	83	88	88	88	—
WSP144, NJ	99	95	104	102	104	101
WST109, NH	64	66	68	66	66	66
YEL408, WY	61	62	65	67	67	65
YOS404, CA	79	88	86	88	86	89
Number of Sites ≥ 85 ppb	**24**	**26**	**33**	**34**	**23**	**20**

Note:
* values greater than or equal to 85 ppb are shaded
** In October 2000, WEL149 was moved 5 miles southeast to Hoxeyville, MI and renamed HOX148.

Table 4-3. Number of Days that 8-Hour O_3 Concentrations Equaled or Exceeded 85 ppb (1995-2002) (Page 1 of 2)

Site ID	1995	1996	1997	1998	1999	2000	2001	2002
ABT147, CT	11	3	11	7	8	5	14	13
ACA416, ME				4	5		9	6
ALH157, IL	13	9	9	10	10	4	2	13
ANA115, MI	2	3	2	5	11	2	4	7
ARE128, PA	15	8	7	21	8	3	16	26
ASH135, ME								1
BEL116, MD	19	5	20	24	25	8	16	24
BFT142, NC			2	6	2			1
BVL130, IL	9	8	3	8	8	4		8
BWR139, MD	16	10	25	30	24	10	11	18
CAD150, AR	1			4	7			3
CAT175, NY	5		3	1				1
CDR119, WV		1	1	8	5	2	1	1
CDZ171, KY	7	1	1	11	8	1		4
CHE185, OK								2
CKT136, KY	8	5		12	11			10
CND125, NC	1	7	4	18	16	3	2	8
CNT169, WY						2		
COW137, NC				1	1	2		
CTH110, NY	3	2	1	5	1	1	3	6
CVL151, MS	2			6	8	2		2
DCP114, OH	5	10	5	19	16	4	2	11
DEV412, CA				1	1		2	2
ESP127, TN		1	2	2	4	1		1
EVE419, FL					2			
GAS153, GA	13	12	6	19	25	7	3	6
GRS420, TN				35	37	11	4	32
HOW132, ME	1				1			1
HOX148, MI							5	4
HWF187, NY								1
JOT403, CA	27	48	43	19	38	27	1	33
KEF112, PA	3	1		6	1	2	7	5
LAV410, CA		1		1	2			
LRL117, PA	7	1	6	5	1			3
LYE145, VT	3		2	3			1	12
LYK123, OH	5		5	8	8	2	6	19
MAC426, KY								4
MCK131, KY	11	4	3	15	15	2		9
MCK231, KY	10	3	3	14	15	3		9
MKG113, PA	9	5	1	11	7	1	10	11
OXF122, OH	7	5	4	9	15	4		15
PAR107, WV	3	2	1	4	3	3		

Table 4-3. Number of Days that 8-Hour O_3 Concentrations Equaled or Exceeded 85 ppb (1995-2002) (Page 2 of 2)

Site ID	1995	1996	1997	1998	1999	2000	2001	2002
PED108, VA	2		2	11	5		3	3
PIN414, CA	3	9	1	5	1		2	5
PNF126, NC				7	4	5	1	2
PRK134, WI					3		2	
PSU106, PA	6	2	7	4	12	3	7	14
QAK172, OH	15	2	4	20	12	2	6	4
ROM206, CO								2
ROM406, CO				1	1	2		6
SAL133, IN	10	8	4	3	11	3	3	10
SEK402, CA			45	31	73	52	40	81
SHN418, VA	5	1	6	22	15	1	8	6
SND152, AL	7	6	2	23	23	5	3	6
SPD111, TN	3		2	8	6	6	2	11
STK138, IL	2	5		1	4		1	1
SUM156, FL				2		1		
UVL124, MI	6	5	3	3	11	2	4	6
VIN140, IN	6	6	2	5	9	3	1	11
VPI120, VA	1	1	3	12	12	2	1	6
WEL149, MI	6	3	1	4	12	1		
WSP144, NJ	20	10	7	24	26	12	13	23
WST109, NH		1	1					
YOS404, CA		10	3	9	4	6	4	24

Figure 4-1. Annual Mean O_3 Concentrations (ppb) for 2002

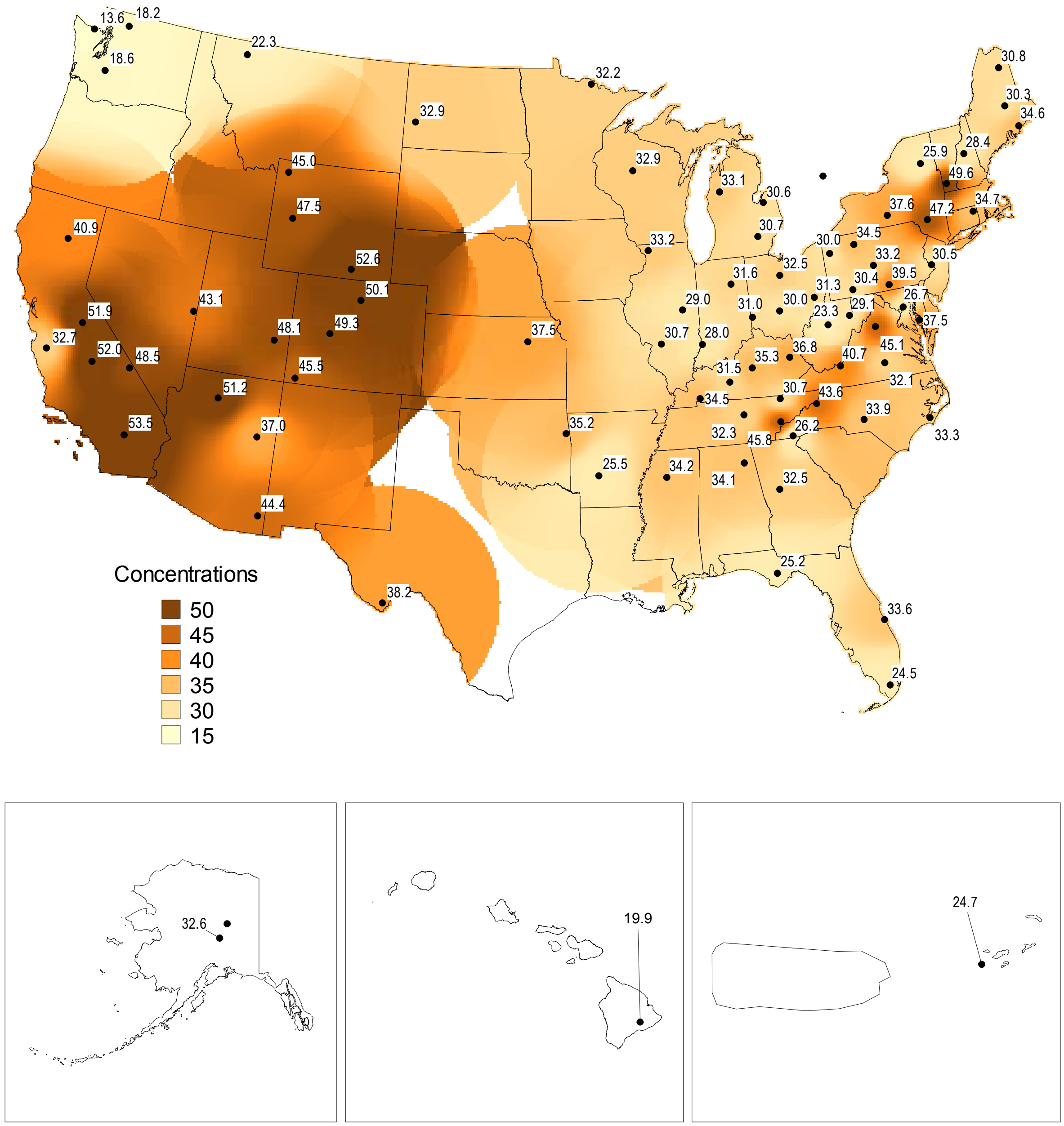

Figure 4-2. Diurnal Cycle of Hourly Mean Ozone Concentrations (ppb) for 2002

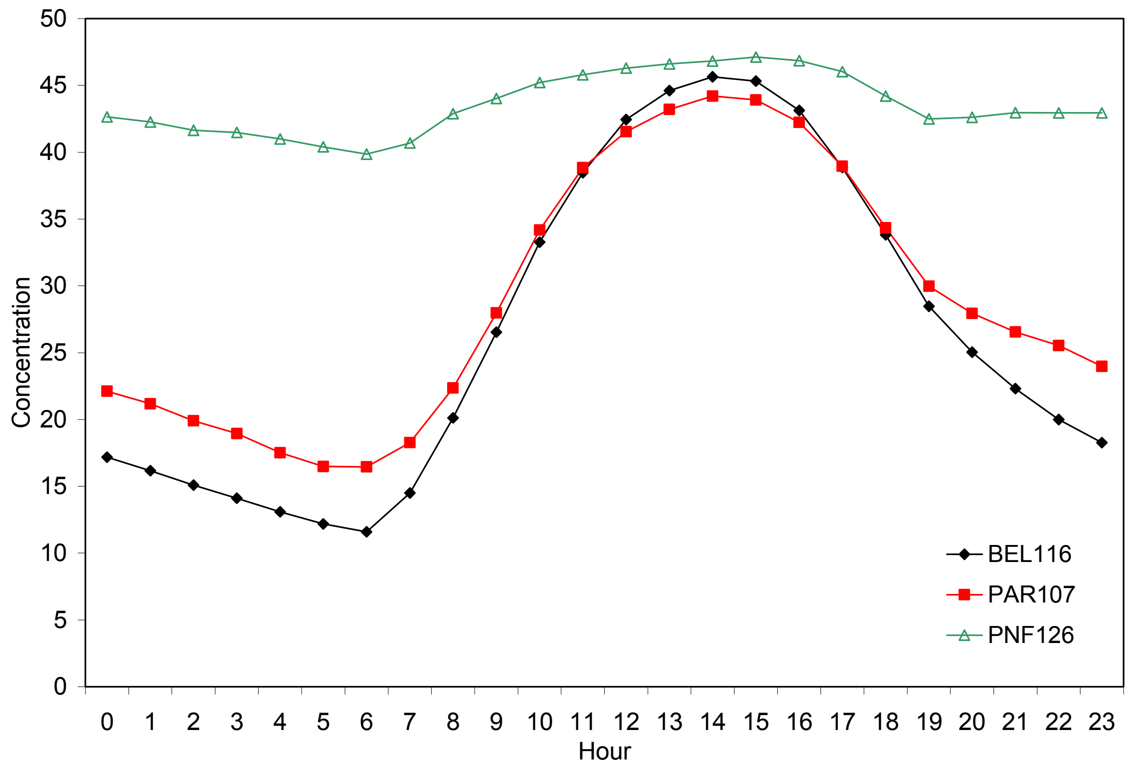

Figure 4-3. Time Series of Peak Daily 1-Hour Ozone Concentrations (ppb) for 2002

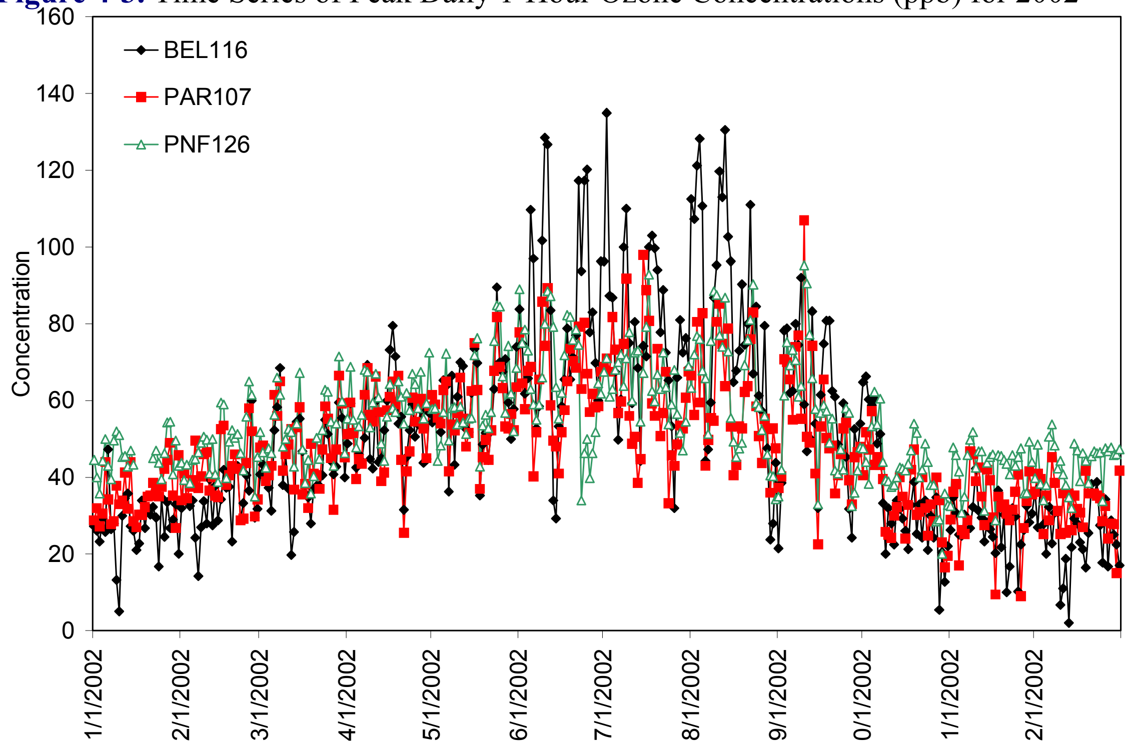

Figure 4-4. Second Highest Daily Maximum 1-Hour O_3 Concentrations (ppb) for 2002

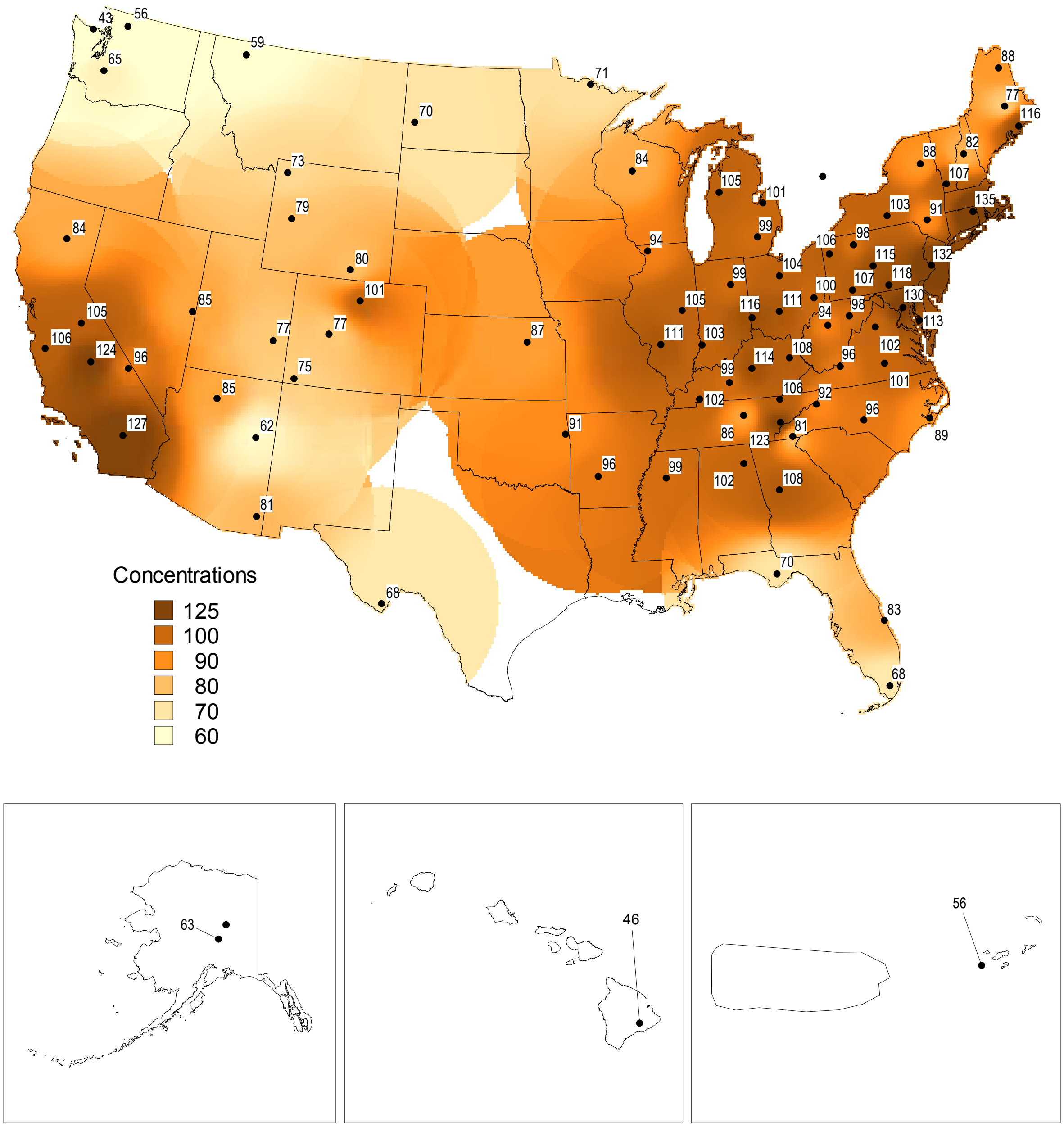

Figure 4-5. Fourth Highest Daily Maximum 8-Hour O_3 Concentrations (ppb) for 2002

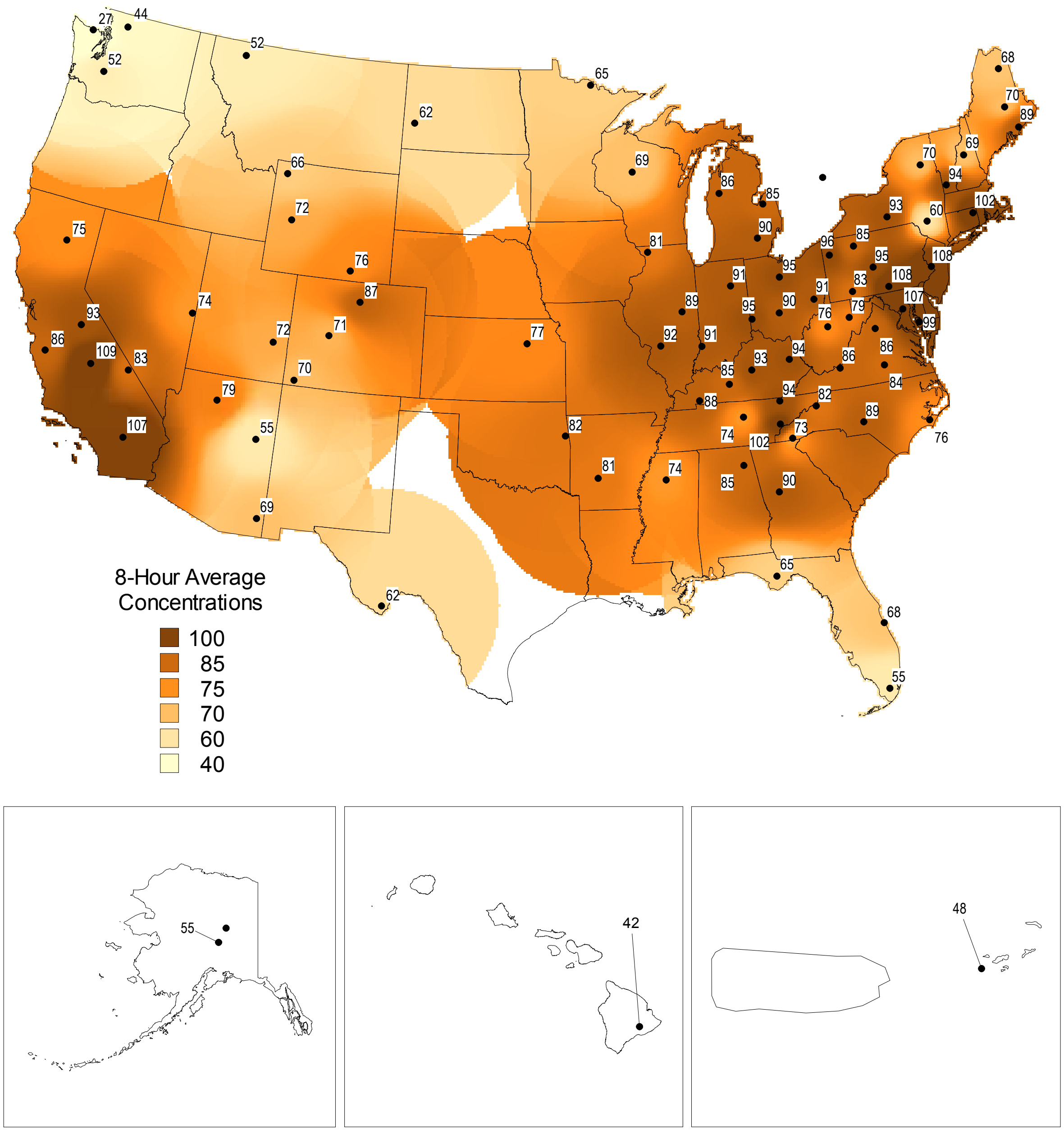

Figure 4-6. Peak SUM06 Values (ppm-hr) for 2002

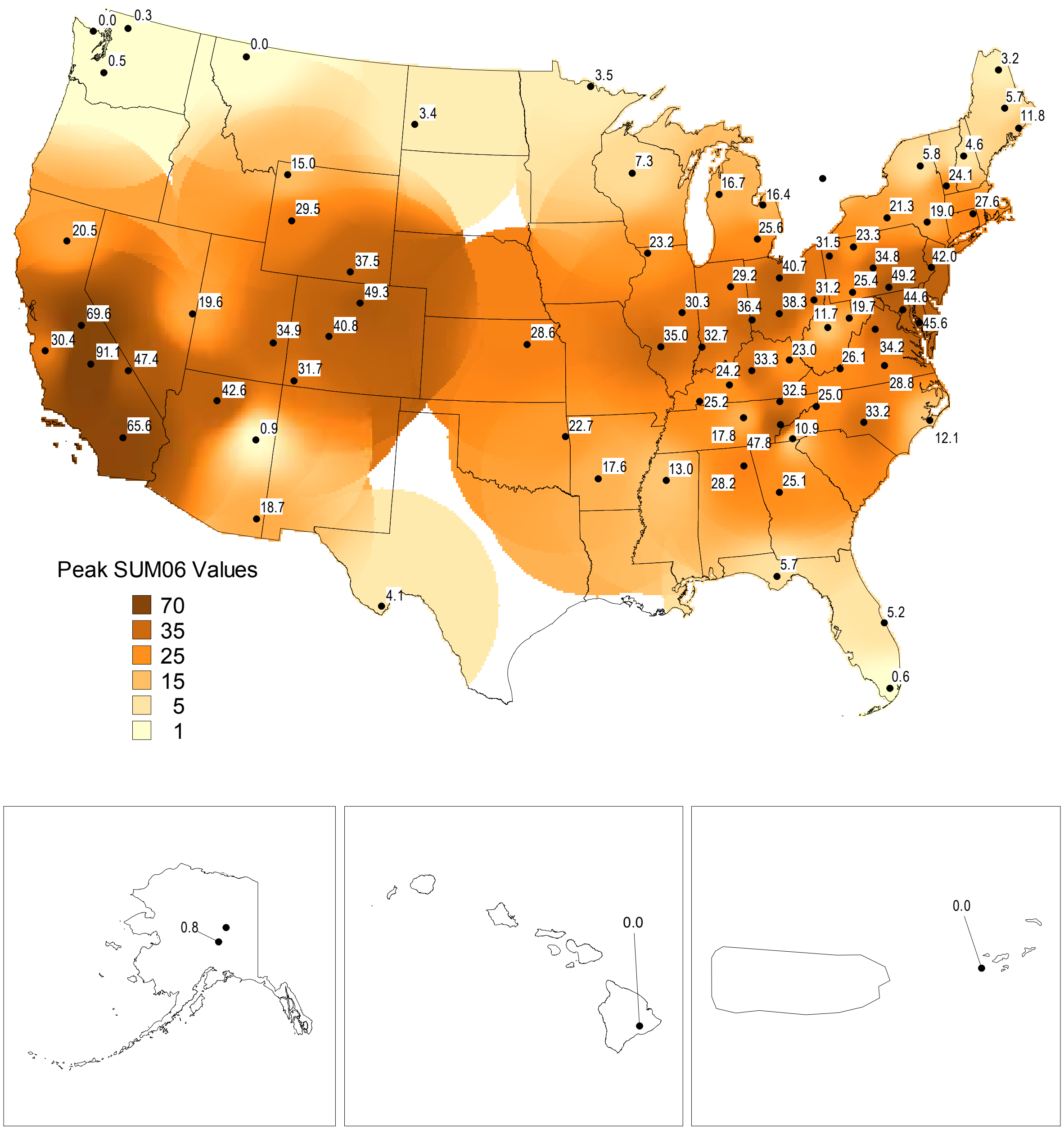

Figure 4-7. Modeled Dry Deposition O_3 Fluxes (kg/ha/yr) for 2002

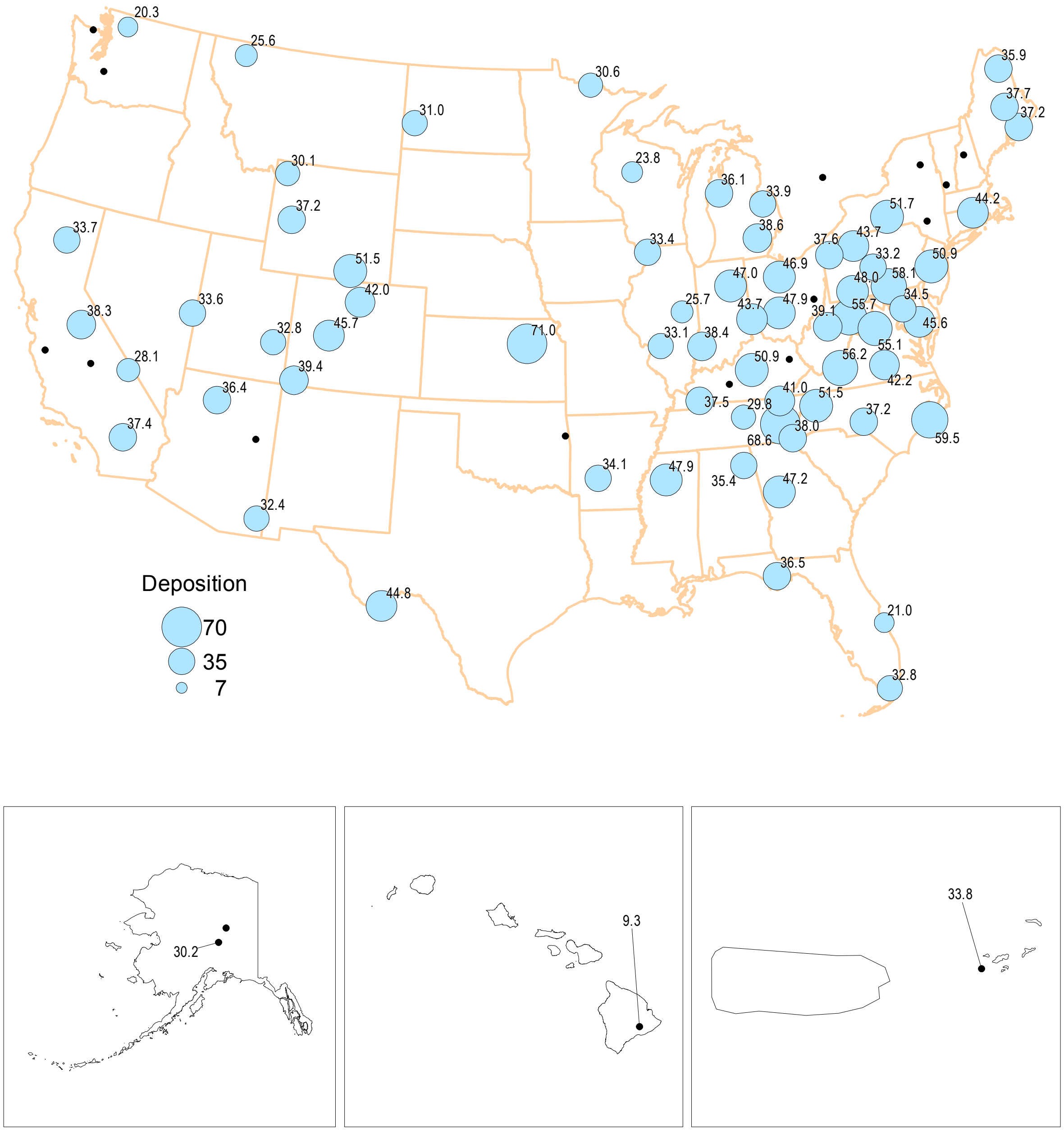

Figure 4-8. Trend in Second Highest Daily Maximum 1-Hour O_3 Concentrations (ppb) — Eastern United States

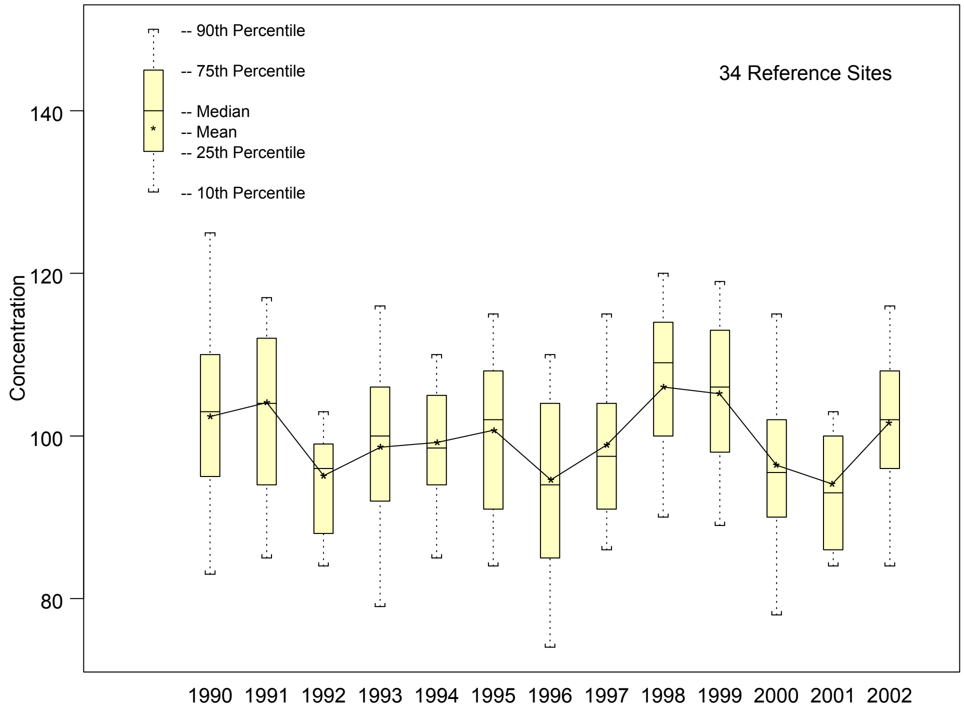

Figure 4-9. Trend in Fourth Highest Daily Maximum 8-Hour O_3 Concentrations (ppb) — Eastern United States

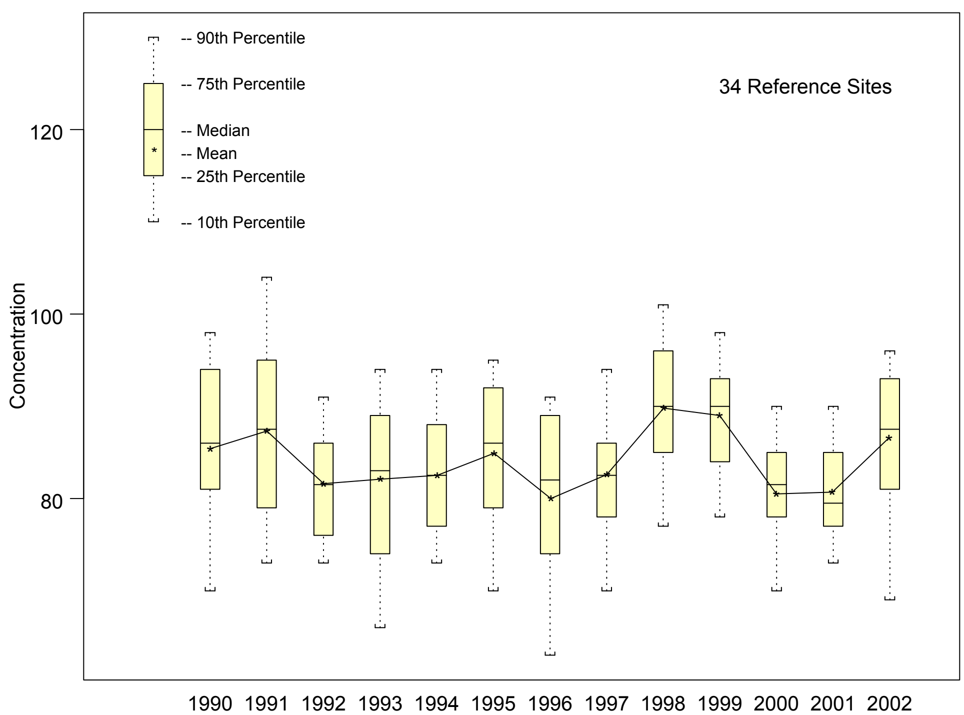

Figure 4-10. Trend in Peak SUM06 Values (ppm-hr) — Eastern United States

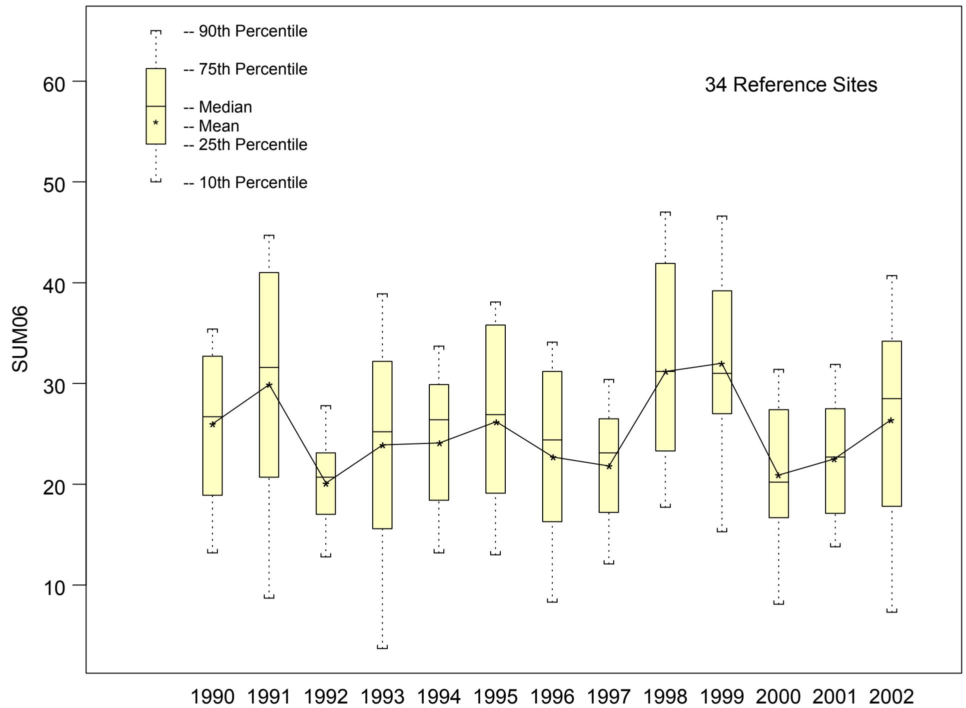

Figure 4-11. Trend in Mean Seasonal Temperature (°C) (May through September)

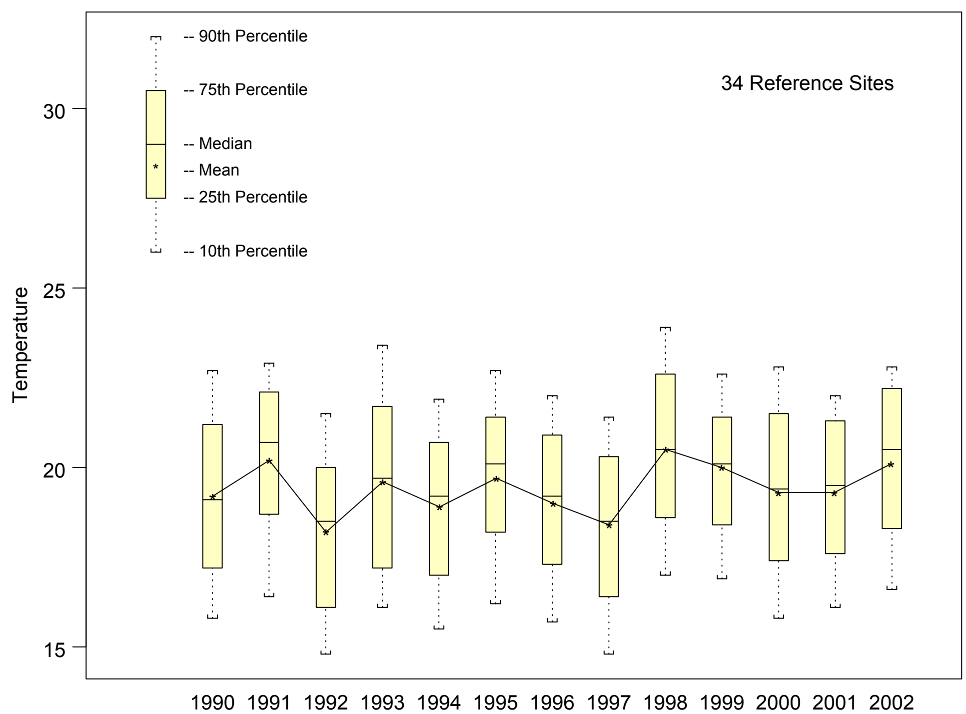

Figure 4-12. Trend in Mean Seasonal Solar Radiation (W/m^2) (May through September)

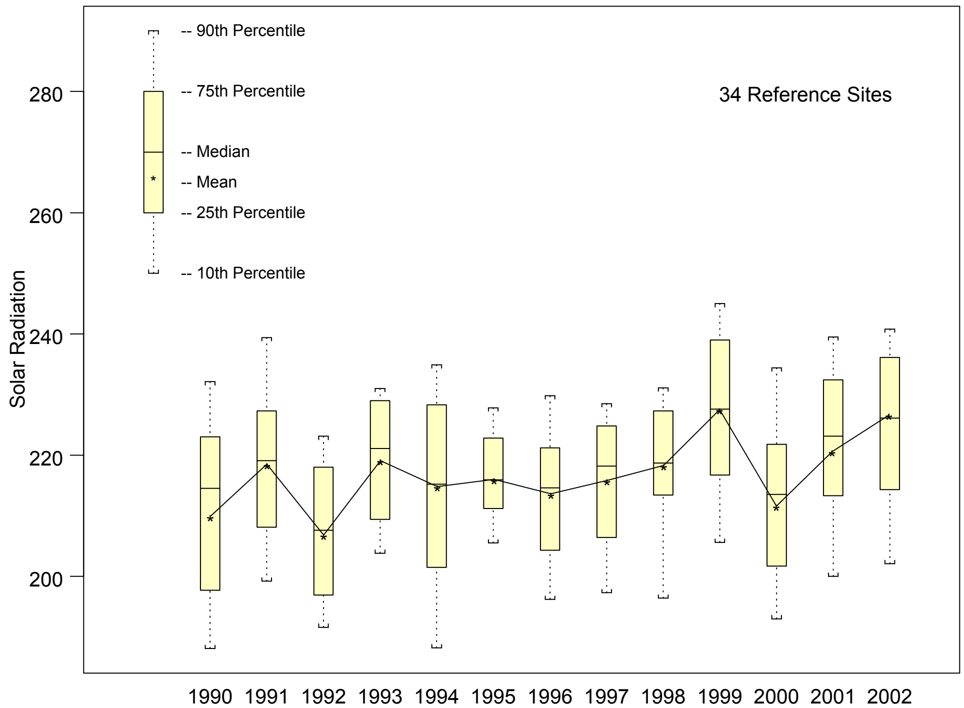

Figure 4-13. Trend in Total Precipitation (mm) (May through September)